# SOME PERFORMANCE STATISTICS OF DOPPLER SODARS AS A FUNCTION OF ATMOSPHERIC CONDITIONS

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## 1 INTRODUCTION

Many regulatory air quality programs often require periods of long-term monitoring in order to develop an assessment of how various meteorological conditions affect pollution concentrations and distributions. Ultimately, these data are used in various diagnostic and/or prognostic models. Reliable model results require, in part, reliable data input. Therefore, a quantitative assessment of the uncertainty in these measurements is needed to provide confidence in model results. This is especially true for data acquired by Doppler sodars which vary in quality for different atmospheric conditions (Crescenti, 1997).

## 2 DATA

A ground-based remote sensor characterization study was conducted for three weeks in April 1995 at the Boulder Atmospheric Observatory (BAO) in Erie, Colorado. The BAO tower was instrumented with R. M. Young Co. wind monitors at 10, 50, 100, 200, and 300 m. These sensors were mounted on booms which were oriented towards the south-southeast (154°). Vaisala HMP-35 probes were used at the same levels to measure air temperature and relative humidity. An Eppley Laboratory Precision Spectral Pyranometer at the surface measured incoming solar radiation. Sodar manufacturers were invited to participate in the study. Four sodars from three companies were deployed about 300 m from the tower. The oblique angle beams were oriented away from the tower so that reflections from the tower and its guy wires were avoided. In addition, this strategy minimized any potential contamination of acoustic pulses from one sodar system to another. Prior to the start of the study, an independent performance audit was performed on the sodars in accordance with the most current guidance available from the U. S. Environmental Protection Agency (U. S. EPA, 1987, 1995). The evaluation included analysis of the site characteristics, sodar alignment, and simulated wind test (Baxter, 1996). No problems with sodar setup was found. Some basic sodar specifications are listed in Table 1. Data from the tower sensors and sodars were recorded as 15-min averages.

Table 1. Doppler sodar specifications.

| | AeroVironment 4000 | Metek MODOS | Radian 600 | Radian 600PA |
|---|---|---|---|---|
| Type | phased-array | 3-beam | 3-beam | phased-array |
| Number of Transducers | 32 | 7 | 1 | 120 |
| Frequency (Hz) | 4500 | 2009 | 1850 | 2125 |
| Pulse Width (ms) | 50 | 150 | 150 | 150 |
| Pulse Interval (s) | 1 | 4 | 4 | 4 |
| Zenith Angle (deg) | 18 | 20 | 18 | 14.87 |
| U/V Beam Direction (deg) | 173 / 83 | 101 / 11 | 302 / 215 | 349 / 259 |
| Min/Max Reported Height (m) | 15 / 200 | 50 / 650 | 50 / 700 | 50 / 700 |
| Resolution (m) | 5 | 25 | 25 | 25 |
| Position with respect to tower | South | Northeast | Northwest | Northwest |

## 3 ANALYSIS

It is well known that the availability of sodar wind data decreases with height. There are many factors which determine the number of valid data returns. One of the most important factors is atmospheric stability. Small-scale temperature inhomogeneities are a necessary mechanism for the backscattering of the acoustic pulse. Pasquill-Gifford (PG) stability classes were determined as a measure of stability by the Solar-Radiation/Delta-T (SRDT) method (Coulter, 1994) using the BAO tower data. Percent data returns are shown in Fig. 1 for the six different PG classes.

The highest percentage of data returns are found for convective (class A, B) conditions while the lowest

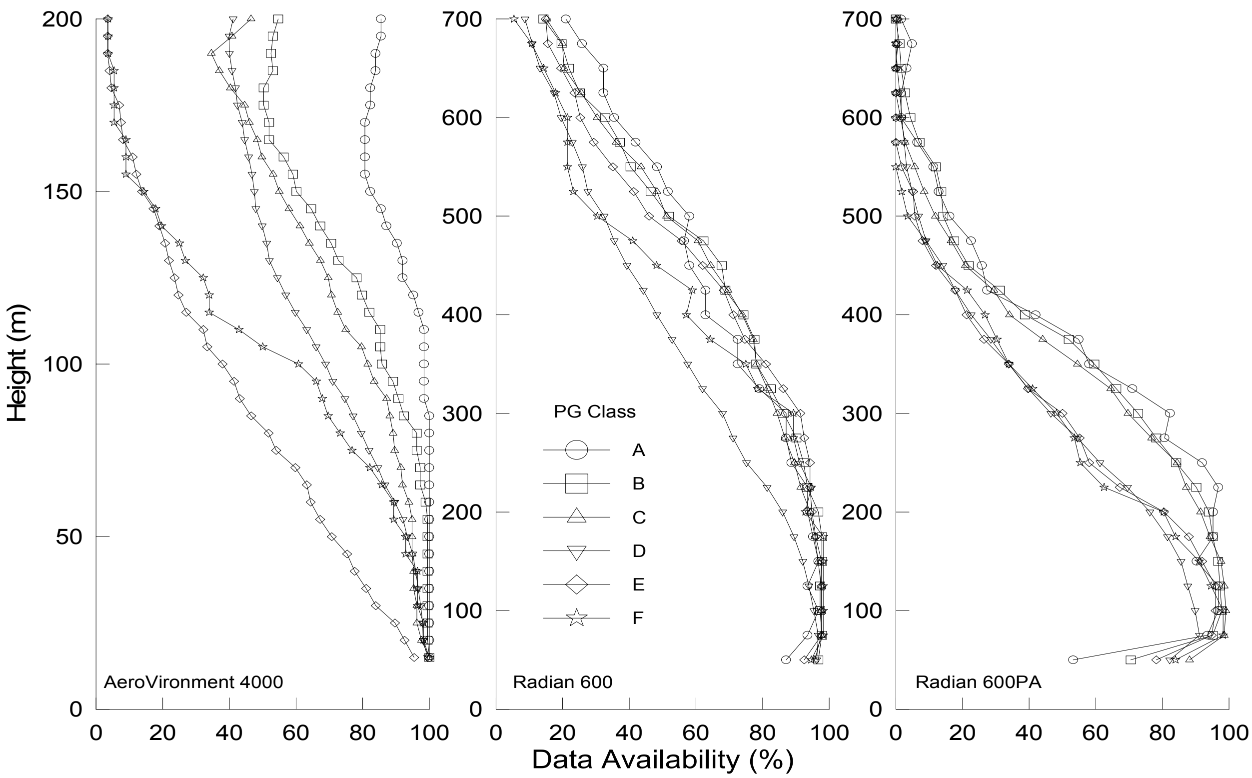

Figure 1. Data availability percentages versus height as a function of PG class.

percentage of data returns are found for stable (class E, F) conditions. The most dramatic differences are found in the AeroVironment sodar data. Large differences are also apparent in the data obtained by the Radian 600PA sodar. As expected, more data is available when the boundary layer is dominated by convection. Under stable conditions, the absence of thermal turbulence and strong ground-based and low-level inversions limit the range of the acoustic pulse. It should be noted that these data availability profiles make no statement about the accuracy of the reported wind values.

The bias (systematic error) $B$, comparability (rms difference) $C$, and precision (standard deviation) $S$ are simple statistics of comparison that are used to assess the overall reliability of sodar data. They are defined (Hoehne, 1971) as

$$B = \frac{1}{N}\sum_{i=1}^{N}(Y_i - X_i) \qquad C = \left[\frac{1}{N}\sum_{i=1}^{N}(Y_i - X_i)^2\right]^{1/2} \qquad S = (C^2 - B^2)^{1/2}$$

where $N$ is the number of observations, $X_i$ is the $i$th observation from the reference instrument, and $Y_i$ is the $i$th observation from the sodar. Values for these statistics were obtained for those cases when the wind was between 19° and 289° (unobstructed flow to the tower) and when the wind speed was greater than 0.5 m s$^{-1}$ (above wind monitor starting threshold) and less than 10 m s$^{-1}$ (significant degradation of sodar data due to wind-generated noise).

The bias of the wind speed for all four sodars at all comparison levels was near zero. Values of precision generally ranged from 0.3 to 1.0 m s$^{-1}$ (Fig. 2). In general, precision tends to worsen with height. This may be due in part to larger separation distances of the oblique angle beams of the sodar and the tower-based instruments. Overall, the best precision was found for very unstable (class A) conditions. The next best precision values were those cases of very stable conditions (class F). In the case of the former, convection provides good backscatter of acoustic signals. While inversions limit the range of acoustic signals for the later case, they are excellent mechanisms for acoustic backscatter. In general, the worst precision was observed for neutral conditions (class D). This is to be expected since the lack of thermally-induced turbulence would result in very little backscatter of the acoustic pulse.

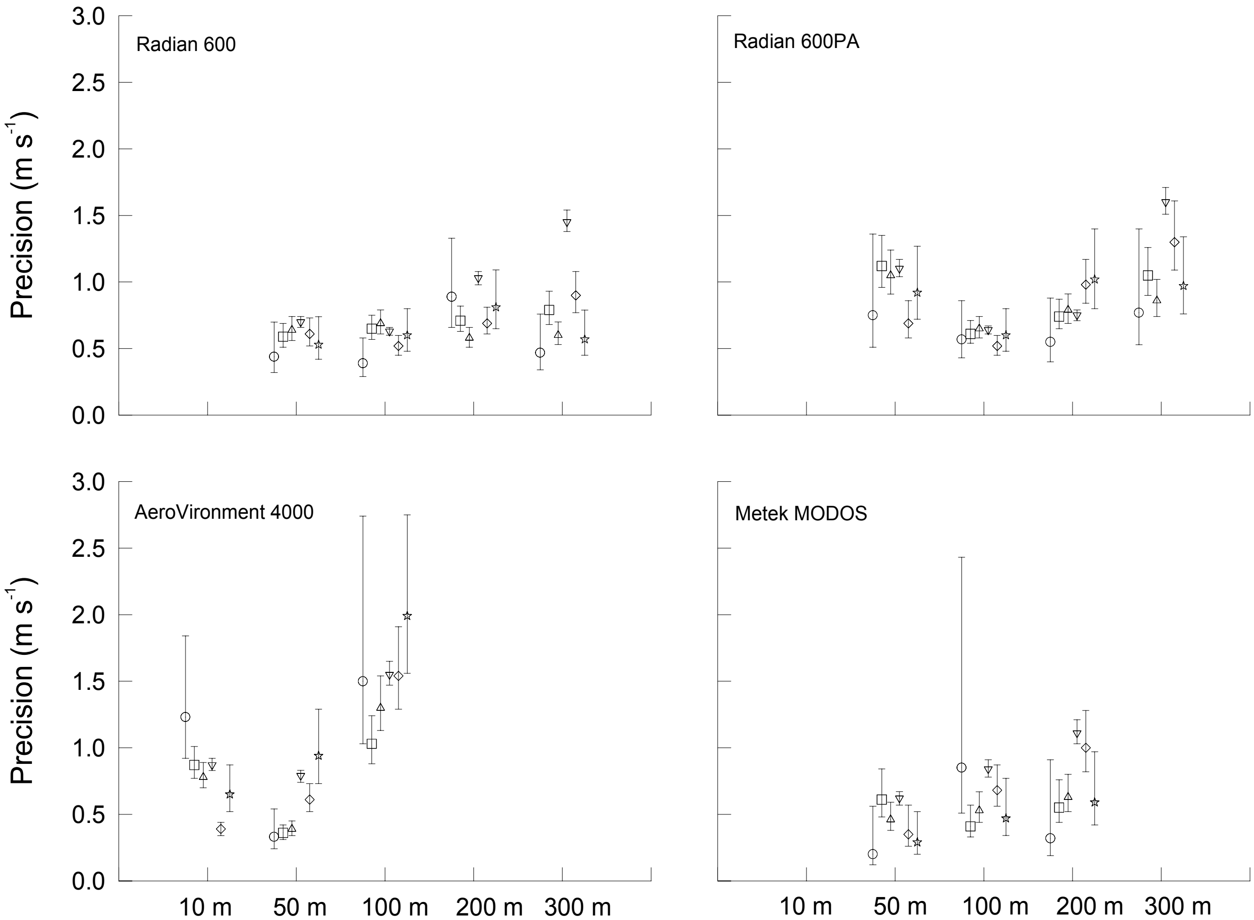


Figure 2. Precision values with 95% confidence limits.

## 4 CONCLUSIONS

Comparison of sodar-derived wind speeds against tower-based measurements show greater data availability for convective conditions (class A, B) than stable (class E, F) conditions. Statistical analysis has shown that sodar-derived wind speeds were in better agreement with tower-based wind speeds for very stable (class A) and very unstable (class F) conditions and were generally worse for neutral (class D) conditions.

## 5 REFERENCES

Baxter, R. A., 1996: Quality assurance of remote wind profilers during the 1995 EPA Sodar Characterization Study. Preprint, *Ninth Joint Conference on the Applications of Air Pollution Meteorology with the AWMA*, Atlanta, GA, Amer. Meteor. Soc., 556-560.

Coulter, C. T., 1994: An evaluation of a solar radiation/delta-T method for estimating Pasquill-Gifford (P-G) stability categories. Preprint, Eighth Joint Conference on the Applications of Air Pollution Meteorology with the AWMA, Nashville, TN, Amer. Meteor. Soc., 40-47.

Crescenti, G. H., 1997: A look back on two decades of Doppler sodar comparison studies. *Bull. Amer. Meteor. Soc.*, **78**, 651-673.

Hoehne, W. E., 1971: Standardized functional tests. NOAA tech. memo. NWST&EL-12, U.S. Dept. Commerce, 23 pp.

U. S. Environmental Protection Agency, 1987: On-Site Program Guidance for Regulatory Modeling Applications. EPA-450/4-87-013, Office of Air Quality Planning and Standards, Research Triangle Park, NC.

U. S. Environmental Protection Agency, 1995: Quality Assurance Handbook for Air Pollution Measurement Systems, Volume IV: Meteorological Measurements. EPA-600/R-94/038d, Office of Research and Development, Research Triangle Park, NC.